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Commercial and Military High Level EM Susceptibility Requirements

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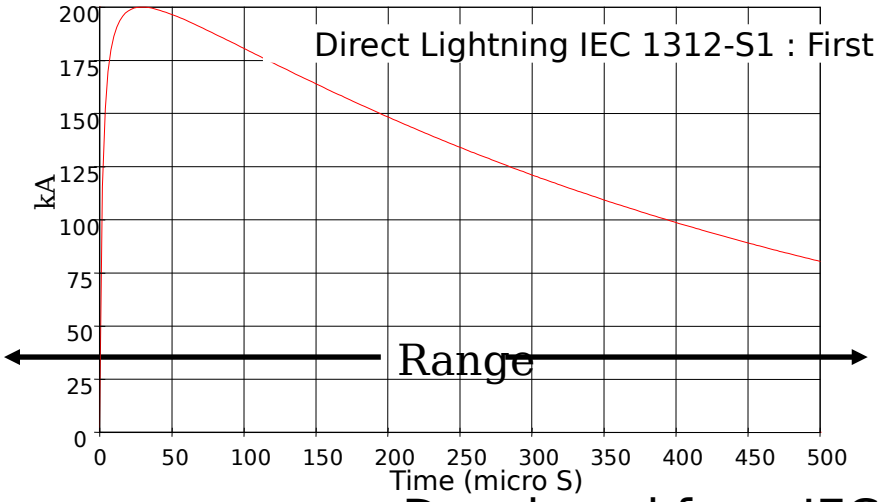
Outline

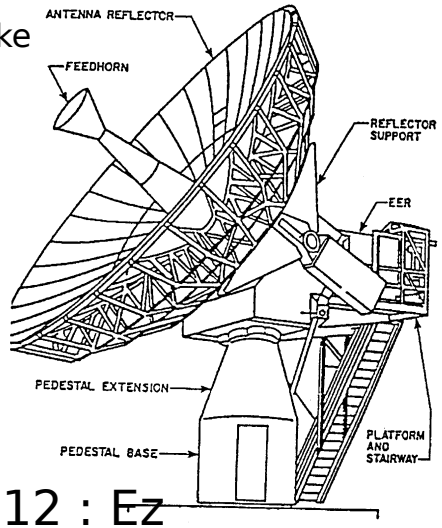
- Introduction
- Environments
- Immunity (Susceptibility) Standards
- Comparisons of Commercial and Military Requirements
- Unified EM Design Code - - A Tool for Generating Combined Protection Requirements
- Satellite Terminal Protection Example
- Conclusions

High Level EM Environments And Immunity Standards

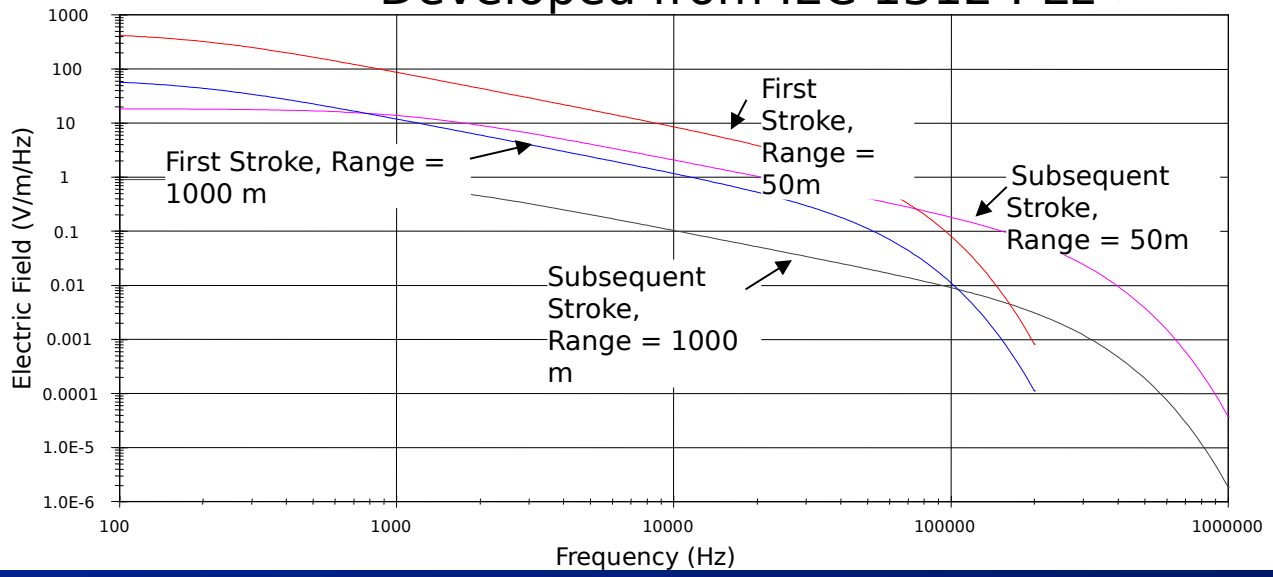
HIGH LEVEL ENVIRONMENTS			STANDARDS	
Environment	Type	Waveform	Environment	Immunity
Nearby Lightning	Natural	Pulse	MIL-STD 464	MIL-STD 461 CS116 MIL-STD 461 RS103 RTCA/DO160 Sec 22 IEC 61000-4-9 IEC 61000-4-10 IEC 61000-4-5 IEC 61000-4-12
Direct Lightning	Natural	Pulse	MIL-STD 464 IEC 1312 -1 RTCA/DO-160	RTCA/DO-160, Sec 23
HEMP (E1, E2, E3)	Hostile	Pulse	MIL-STD 2169B MIL-STD 188-125 MIL-STD 464 IEC 61000-2-9	MIL-STD 461 CS116 MIL-STD 461 RS105 IEC 61000-4-20 IEC 61000-4-25
HIRF	Electronic Operation	CW, Modulated CW	MIL-STD 464	MIL-STD 461 CS114 MIL-STD 461 RS103 RTCA/DO-160 Sec 20 IEC 61000-4-3 IEC 61000-4-6
RF Weapons HPM UWB	Hostile	CW, Modulated CW Pulse	-	-
P-Static	Natural	Pulse	-	-

Direct And Nearby Lightning Environmen

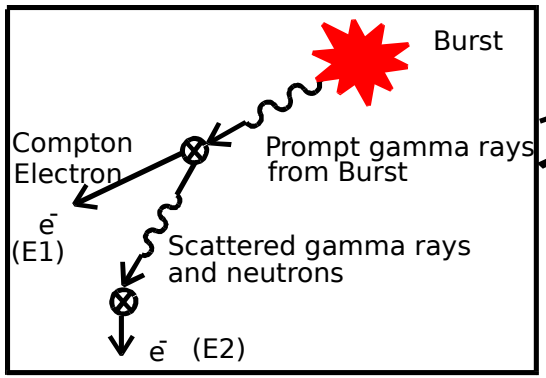


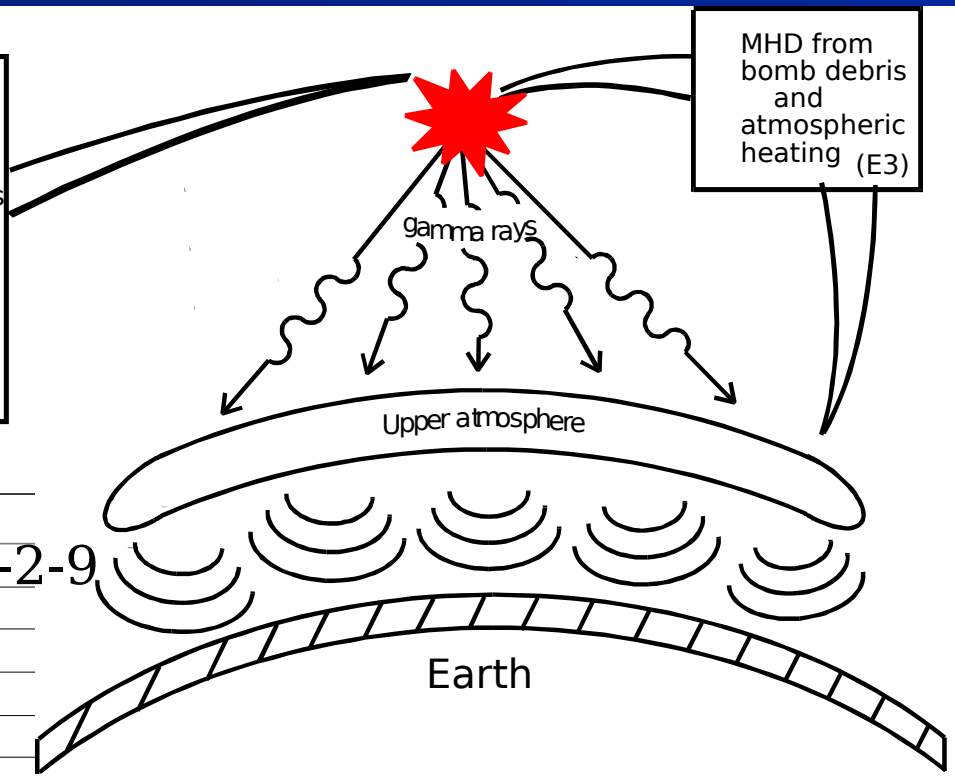


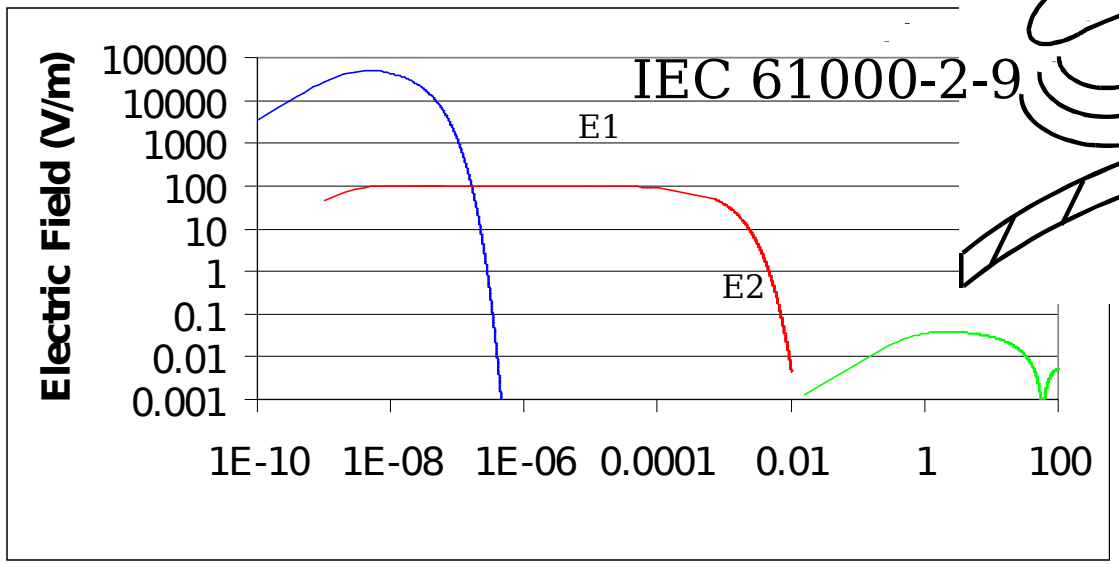
Developed from IEC 1312 : Ez



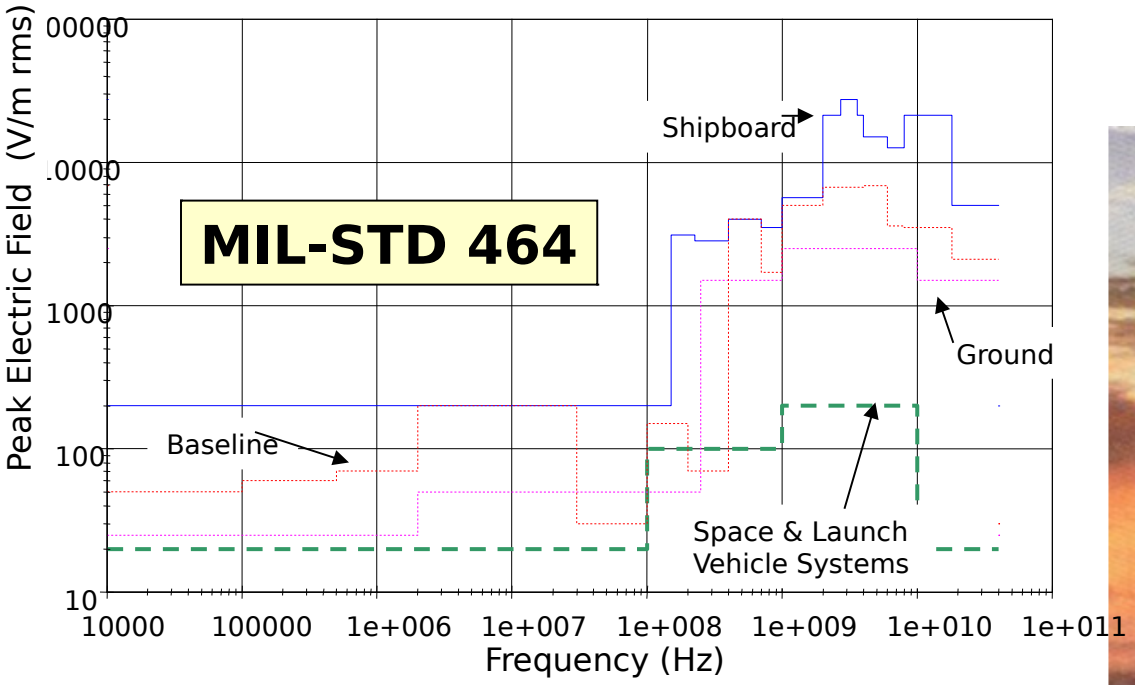
High Altitude EMP Environments

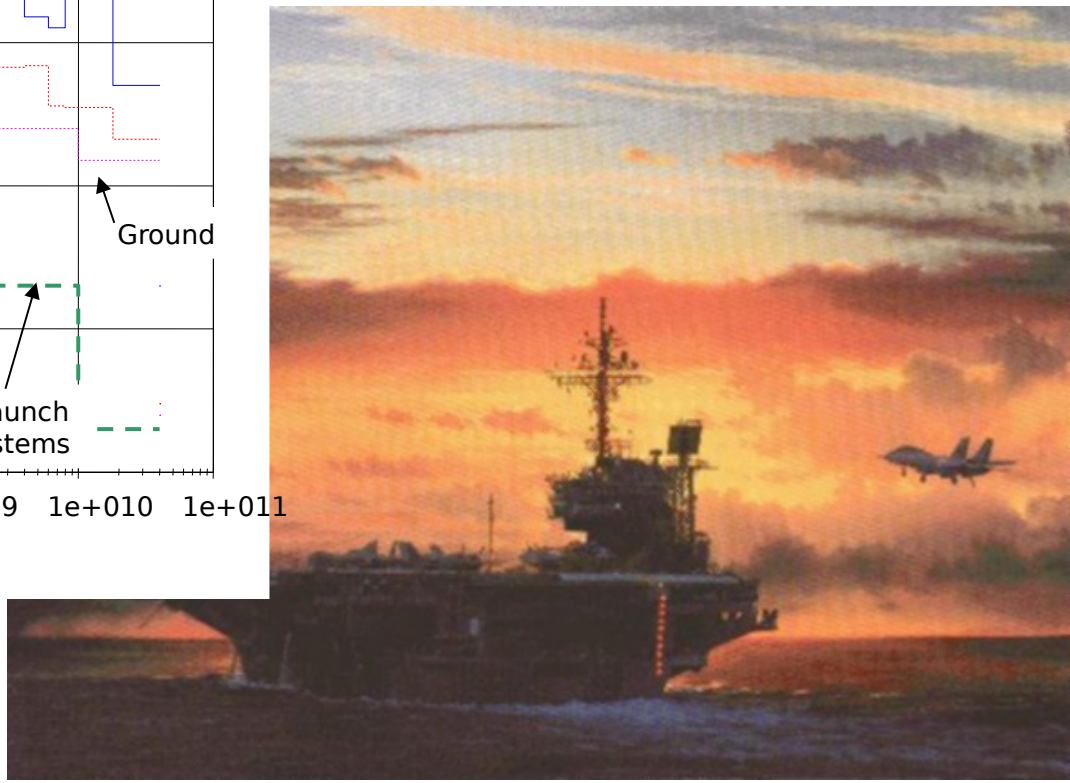




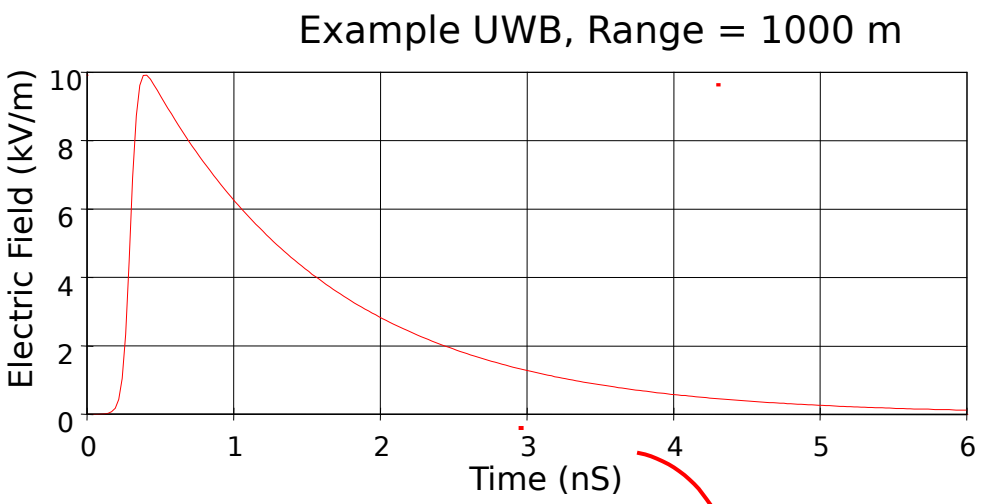


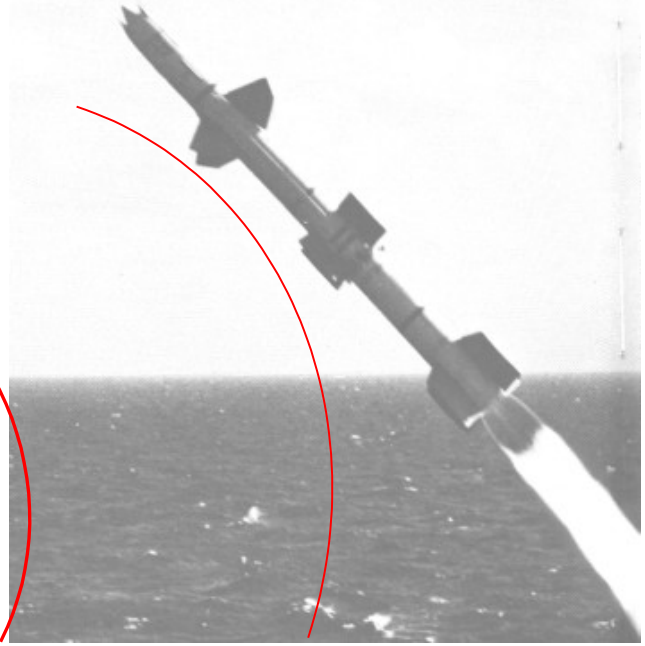
High Intensity Radiated Field (HIRF) Environments

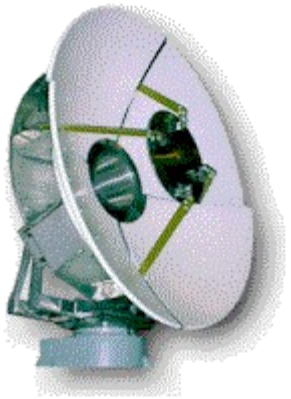




RF Weapon (UWB & HPM) Environment Exa







Hypothetical HPM mission examples (anti-missile defense)

	Case A	Case B	Case C
Power, Freq	10 GW, 10 GHz	3 GW, 30 GHz	0.3 GW, 30 GHz
PRF, Width	10 Hz, 50 ns	10 Hz, 50 ns	10 Hz, 50 ns
Ant. Gain	10^5	10^6	10^6
Range	10 km	10 km	1 km
Spot Size	100 m	30 m	3 m
Flux	80 W/cm^2	240 W/cm^2	2400 W/cm^2
Fluence	4 μJ/cm^2	12 μJ/cm^2	120 μJ/cm^2
Peak E	18 kV/m	30 kV/m	95 kV/m

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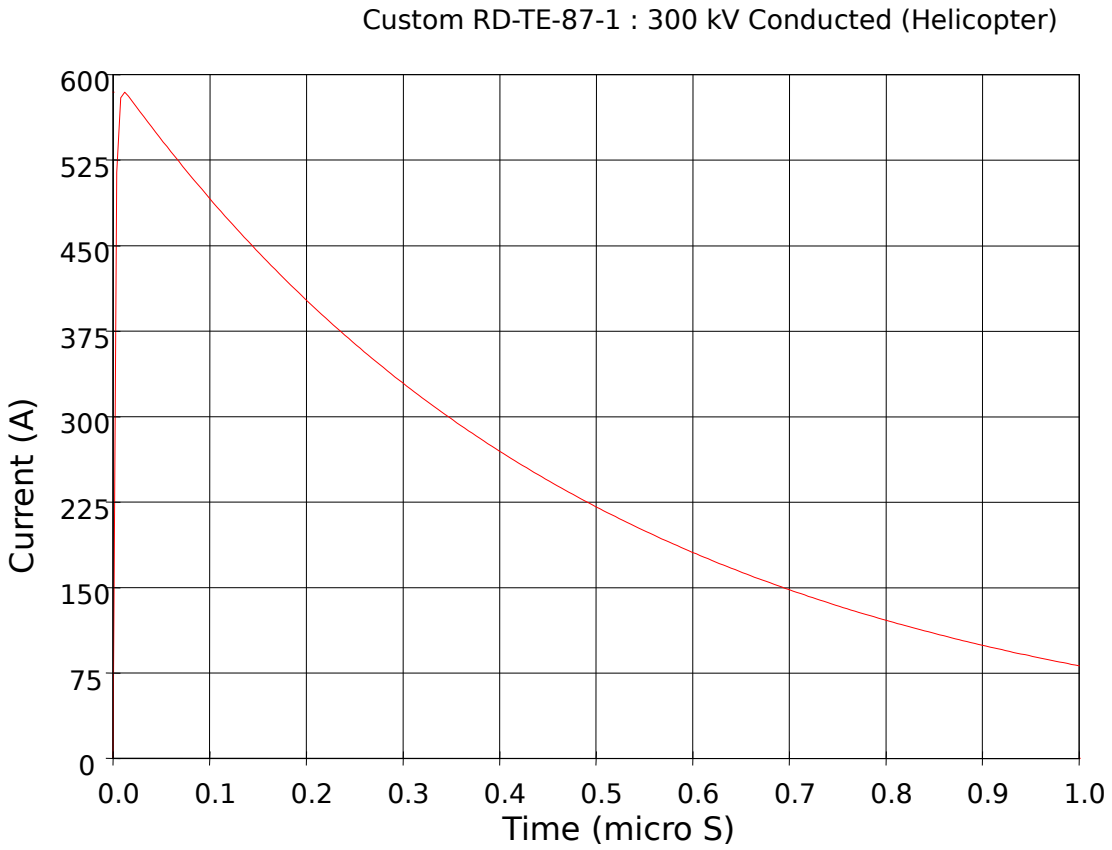
Precipitation Static Environments

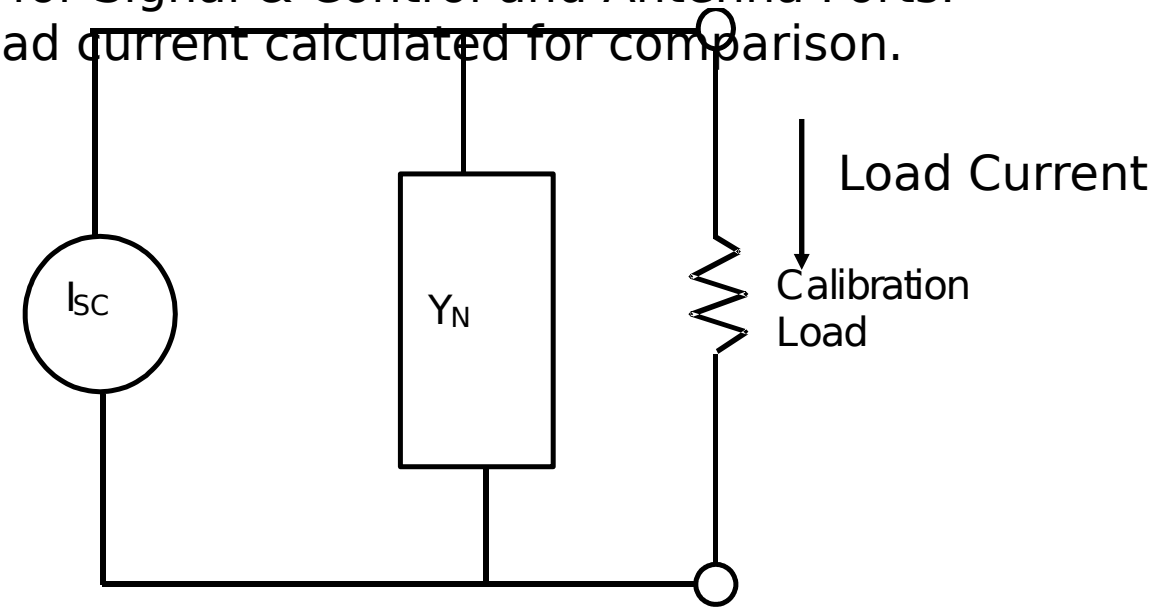


Risetime < 10ns

Based on information in U.S. Army Missile Command technical report [RD-TE-87-1]

Method For Normalizing Immunity Standards

- Develop equivalent source, admittance, Y_N, and short circuit current, I_{SC}.
  - Source specification
  - Coupling circuit
- Standardized load impedance used for each port.
  - 2 ohms for AC and DC Power Ports.
  - 50 Ohms for Signal & Control and Antenna Ports.
- Equivalent load current calculated for comparison.



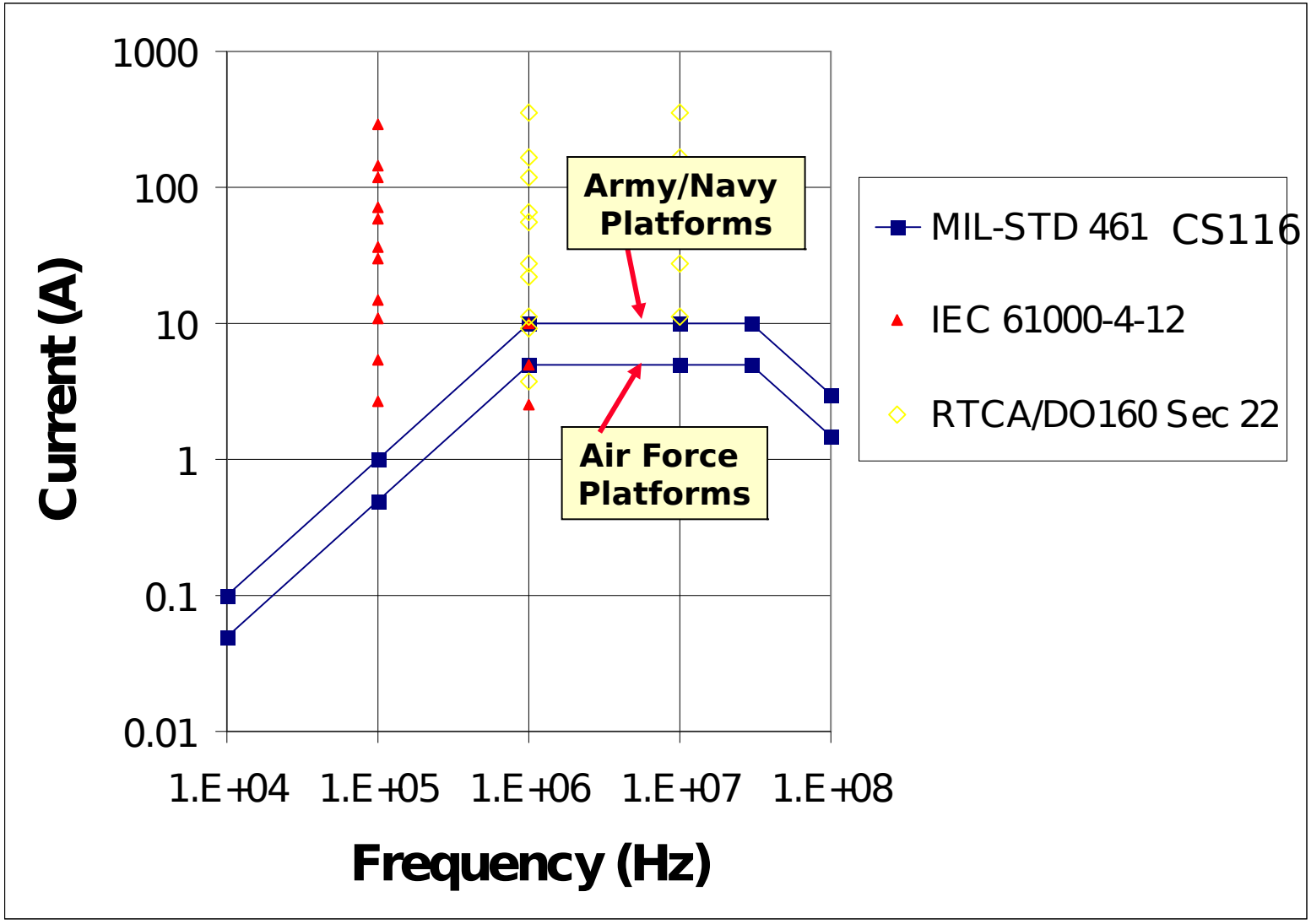
Source Term for Immunity Standards

Damped Sine Wave Immunity Standards

STANDARD	MIL-STD 461 CS116	IEC 61000-4-12	RTCA/DO160 Sec 22
WAVEFORM	Damped Sine	Fast Rise Damped Sine Two waveforms	5 or 6 Waveforms Including Damped Sine
FREQUENCIES	10 kHz, 100 kHz, 1 MHz, 10 MHz, 30 MHz, 100 MHz	100 kHz, 1 MHz	1 MHz, 10 MHz
NUMBER OF LEVELS	2, frequency dependent	4 plus an open level	5
Q	10 to 20	~4 or 50	~10 to 45
SPECIFIED QUANTITY	Cable Current	Source Voltage	Open Circuit Voltage & Short Circuit Current or Source Voltage with Current Limit
CONNECTION METHOD	Inductive Clamp	Capacitive	Direct or Inductive Clamp

- Waveforms have similar characteristics
- Frequency coverage is not the same
- Specified quantity is not the same
- Variety of test method
- Direct comparisons difficult

Example Comparison – Damped Sine Wave Immunities



Narrowband Immunity Standards

Radiated Tests

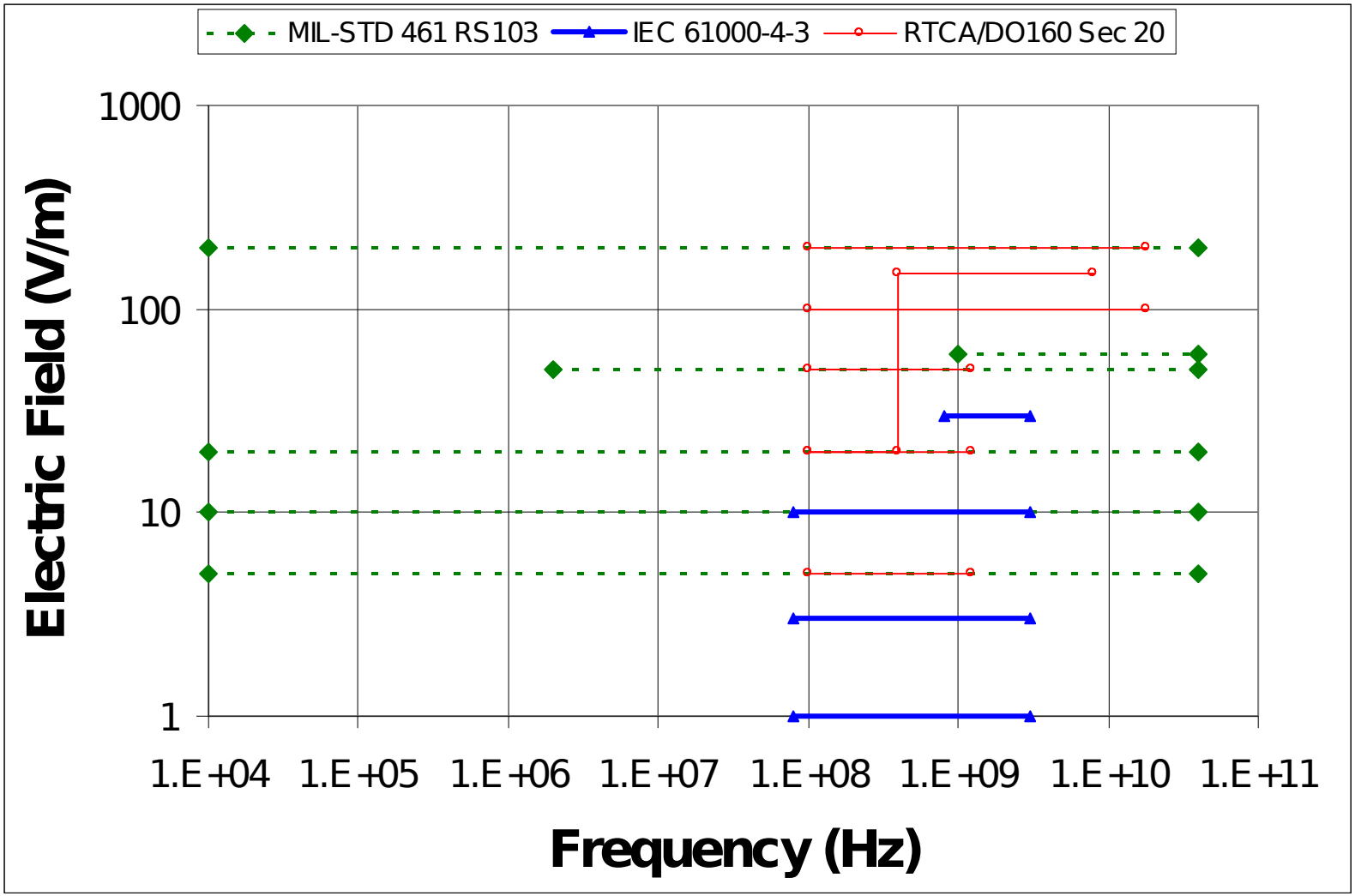
STANDARD	MIL-STD 461 RS103	IEC 61000-4-3	RTCA/DO160 Sec 20
FREQUENCY RANGE	10 kHz to 40 GHz in 5 bands	80 MHz to 3 GHz	100 MHz-18GHz
NUMBER OF LEVELS	6 specified by band for 20 platforms	4 plus an open level	5
SPECIFIED QUANTITY	Electric Field with EUT	Electric Field without EUT	Electric Field without EUT
TEST METHOD	Anechoic or Reverberation Chamber	Anechoic Chamber	Anechoic or Reverberation Chamber

Conducted Tests

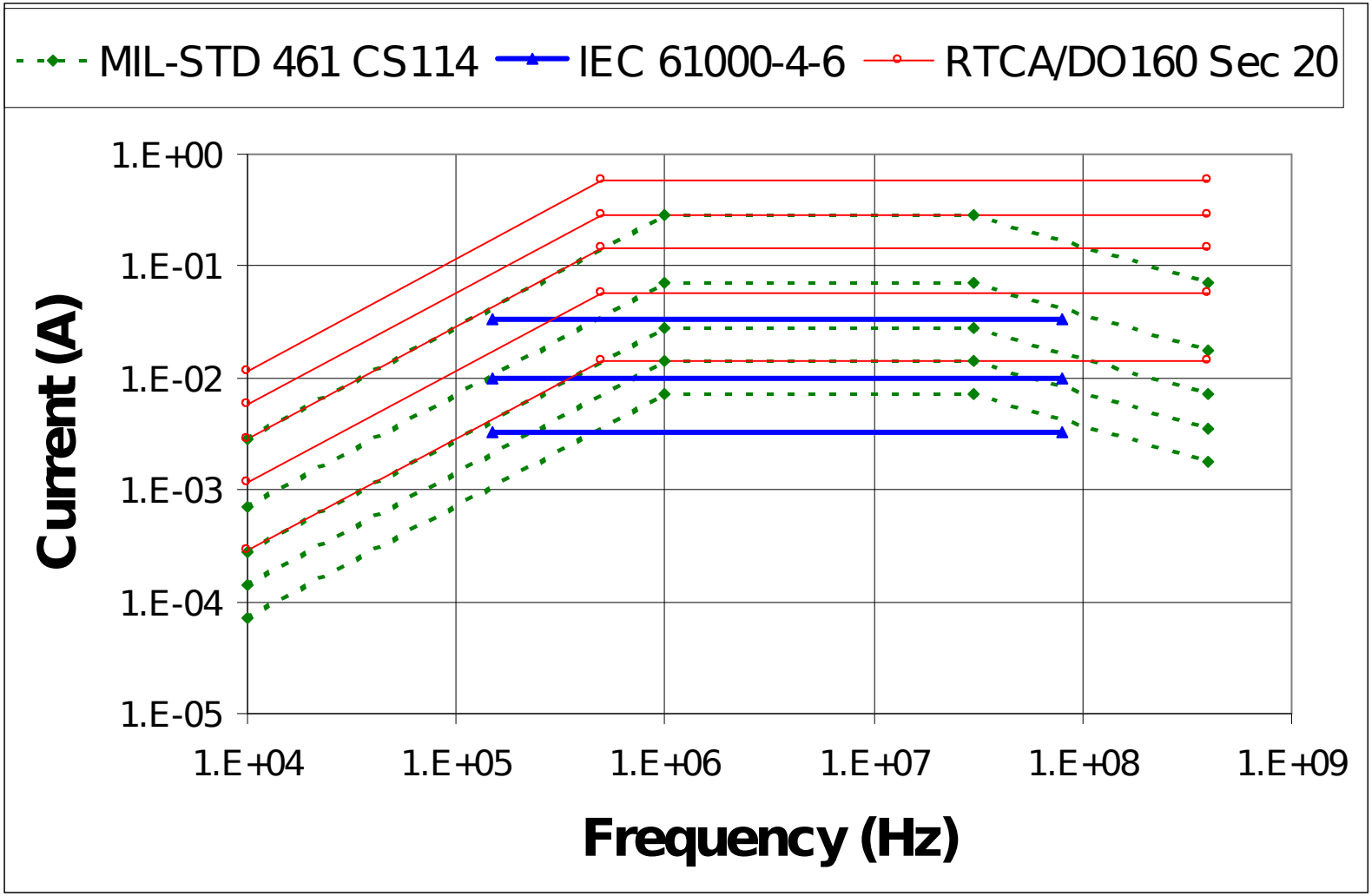
STANDARD	MIL-STD 461 CS114	IEC 61000-4-6	RTCA/DO160 Sec 20
FREQUENCY RANGE	10 kHz to 400 MHz in 4 bands	150 kHz to 80 MHz	10 kHz to 400 MHz
NUMBER OF LEVELS	5 specified by band for 20 platforms	3 plus an open level	5
SPECIFIED QUANTITY	Calibration Load Current	Source Voltage	Calibration Load Current
CONNECTION METHOD	Inductive Clamp	Capacitive, Direct or Inductive Clamp	Inductive Clamp

- Both radiated and conducted standards
- Frequency coverage is not always the same
- Specified quantity is not always the same
- Some variation in test methods
- Direct comparisons possible in some

Narrowband Radiated Immunities Comparison

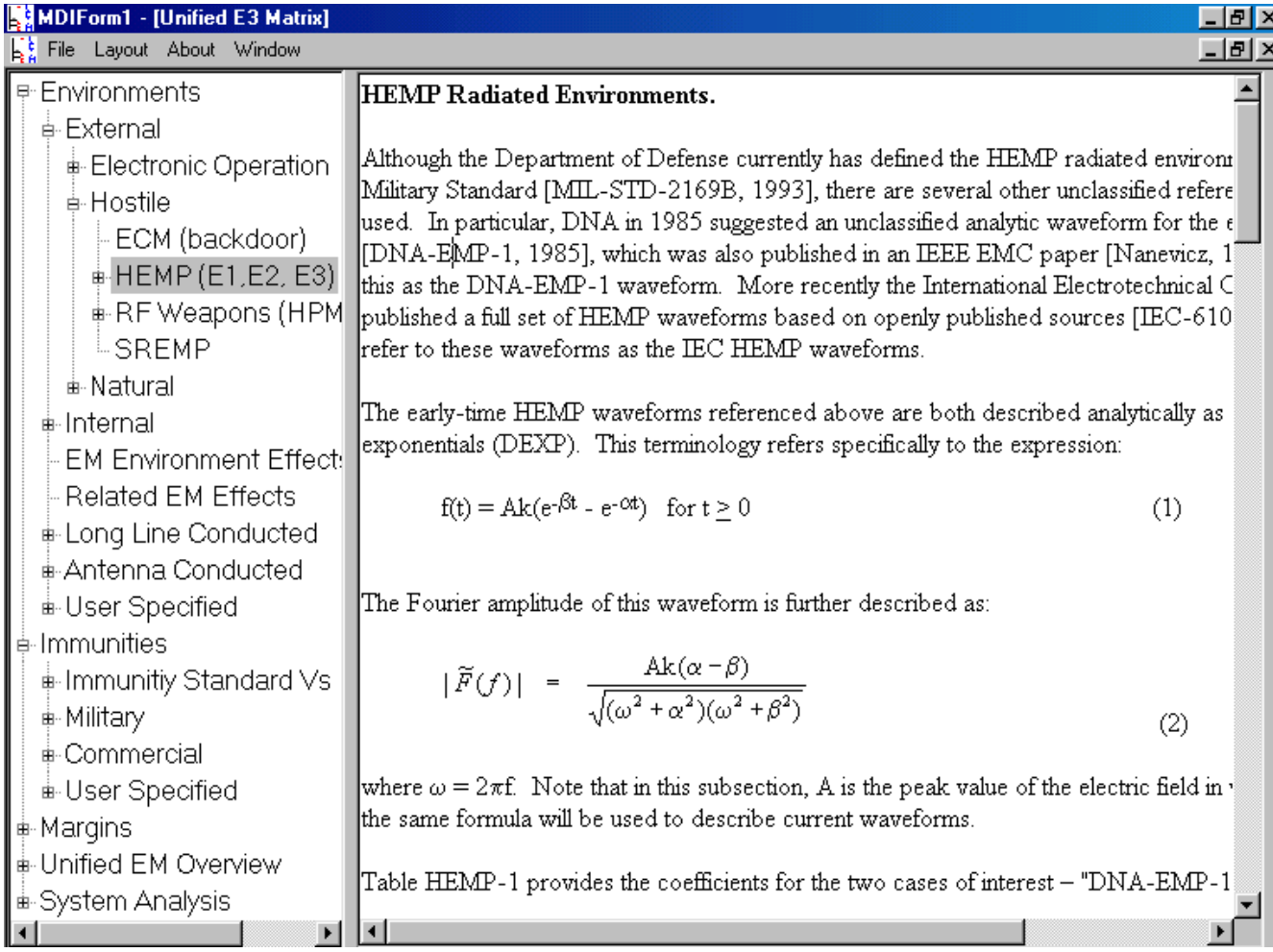


Narrowband Conducted Immunities Comparison



Overview of DTRA's Unified EM Design Software Package

- Provides information on environments and immunities
- Military and commercial standards
- Windows Explorer style operation
- Comparisons in time and frequency domains
- Barrier performance


MDIForm1 - [Unified E3 Matrix]
File
Layout
About
Window
Environments
External
Electronic Operation
Hostile
ECM (backdoor)
HEMP (E1,E2, E3)
RF Weapons (HPM
SREMP
Natural
Internal
EM Environment Effect
Related EM Effects
Long Line Conducted
Antenna Conducted
User Specified
Immunities
Immunitiy Standard Vs
Military
Commercial
User Specified
Margins
Unified EM Overview
System Analysis
HEMP Radiated Environments.
Although the Department of Defense currently has defined the HEMP radiated environ
Military Standard [MIL-STD-2169B, 1993], there are several other unclassified refere
used. In particular, DNA in 1985 suggested an unclassified analytic waveform for the
[DNA-EMP-1, 1985], which was also published in an IEEE EMC paper [Nanevicz, 1
this as the DNA-EMP-1 waveform. More recently the International Electrotechnical C
published a full set of HEMP waveforms based on openly published sources [IEC-610
refer to these waveforms as the IEC HEMP waveforms.
The early-time HEMP waveforms referenced above are both described analytically as
exponentials (DEXP). This terminology refers specifically to the expression:
f(t) = Ak(e^-βt - e^-αt) for t ≥ 0 (1)
The Fourier amplitude of this waveform is further described as:
|F̃(f)| = Ak(α − β) / √((ω² + α²)(ω² + β²)) (2)
where ω = 2πf. Note that in this subsection, A is the peak value of the electric field in
the same formula will be used to describe current waveforms.
Table HEMP-1 provides the coefficients for the two cases of interest – "DNA-EMP-1

Unified EM Matrix Code

PMOs need guidance and EM tools for:

- **Procuring survivable systems and equipment**
- **Leveraging inherent immunity of COTS**
- **Identifying affordable hardening solutions**

Background

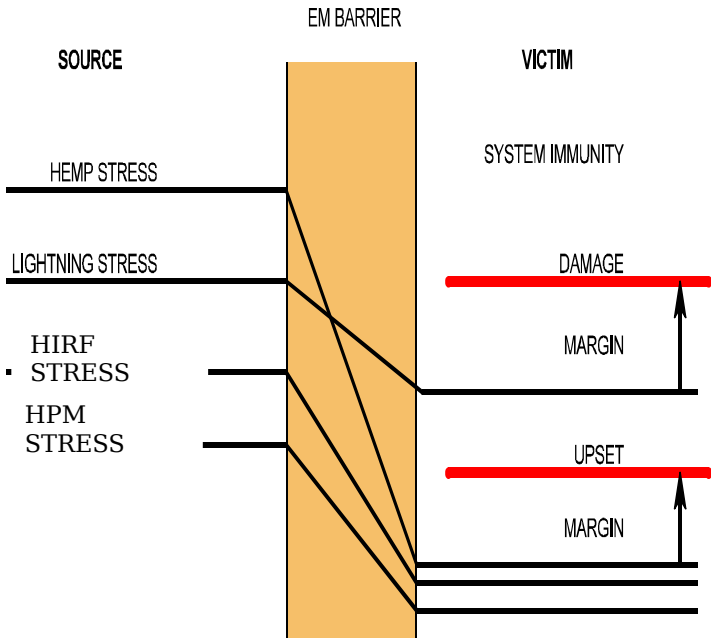
Unified Electromagnetic Design Tool

- **Current prototype software has about 50 users/evaluators**
  - contains substantial number of EM environments and standards
  - Unified E3 methodology adopted into U.S. Army QSTAG 1051 and U.K. design guide
  - Unified methodology is basis for new NATO protection requirements

Benefits

- **Facilitates integration of COTS equipment into military and commercial systems**
  - Provides engineering-based methodology for determining survivability/operability of *installed* COTS
  - Enables “what if” design tradeoffs among environments, immunities, design margin (risk), mitigation methods, and system performance *before* engineering development
- **Enables designers to derive system-level unified EM protection specs**
- **Addresses national/international demand for a simplified EM design tool (e.g., U.S. military contractor community)**
- **Supports Services’ goal of reducing development costs**

Unified E3 Protection Concept



Internal Residual	=	Immunity Margin	-

Barrier Performance Requirement	=	External Environment Stress	-	Internal Residual

Externally Generated EM Environments

- HEMP
- Lightning
- HIRF
- HPM
- UWB
- SREMP
- EME

Radiated Component

Internal Residuals

Barrier Element Performance

Conducted Component

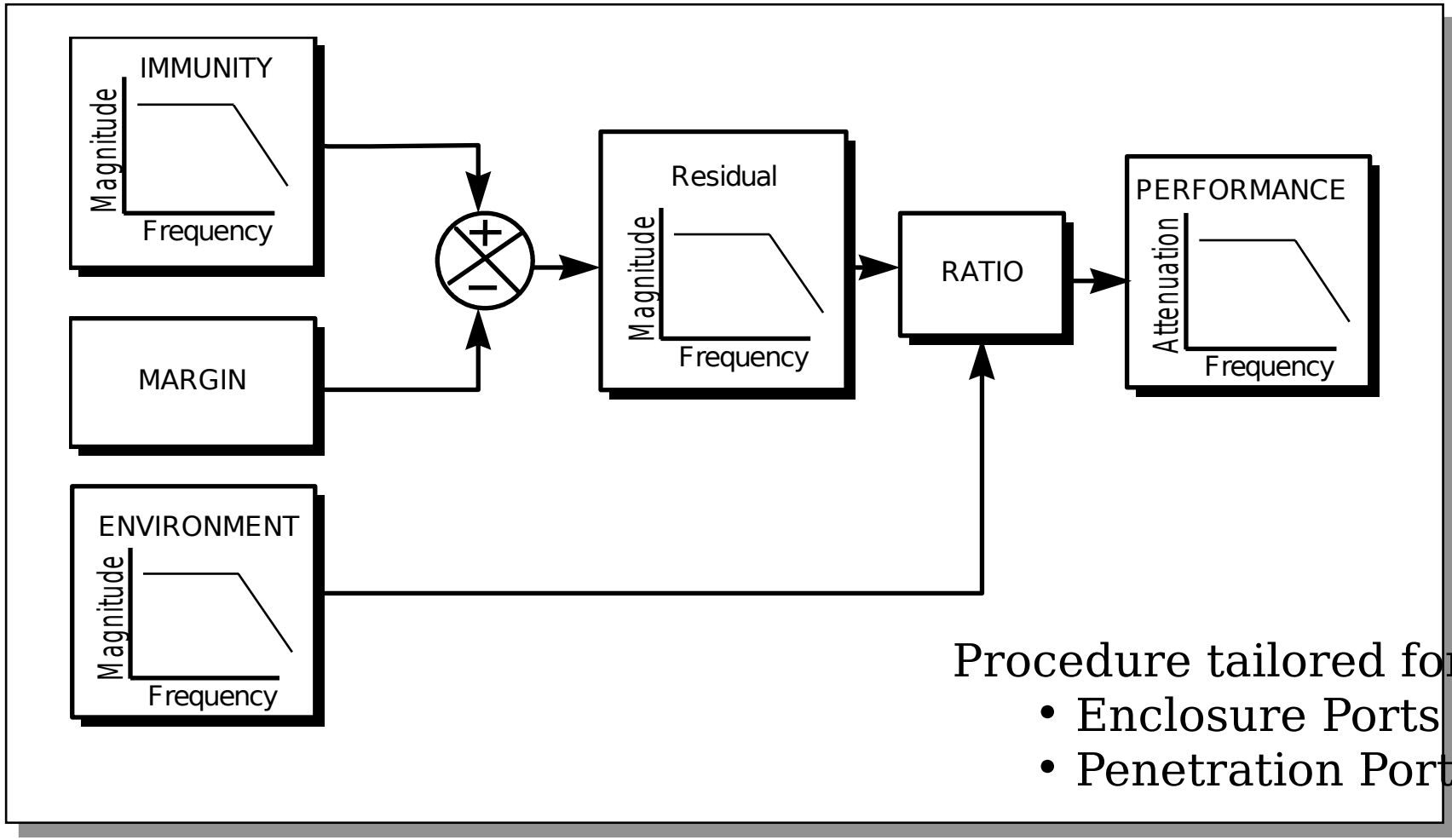
Protected Electronic Equipment with Radiated & Conducted Immunity

Internally Generated Environments

- EMP
- ESD

Margin

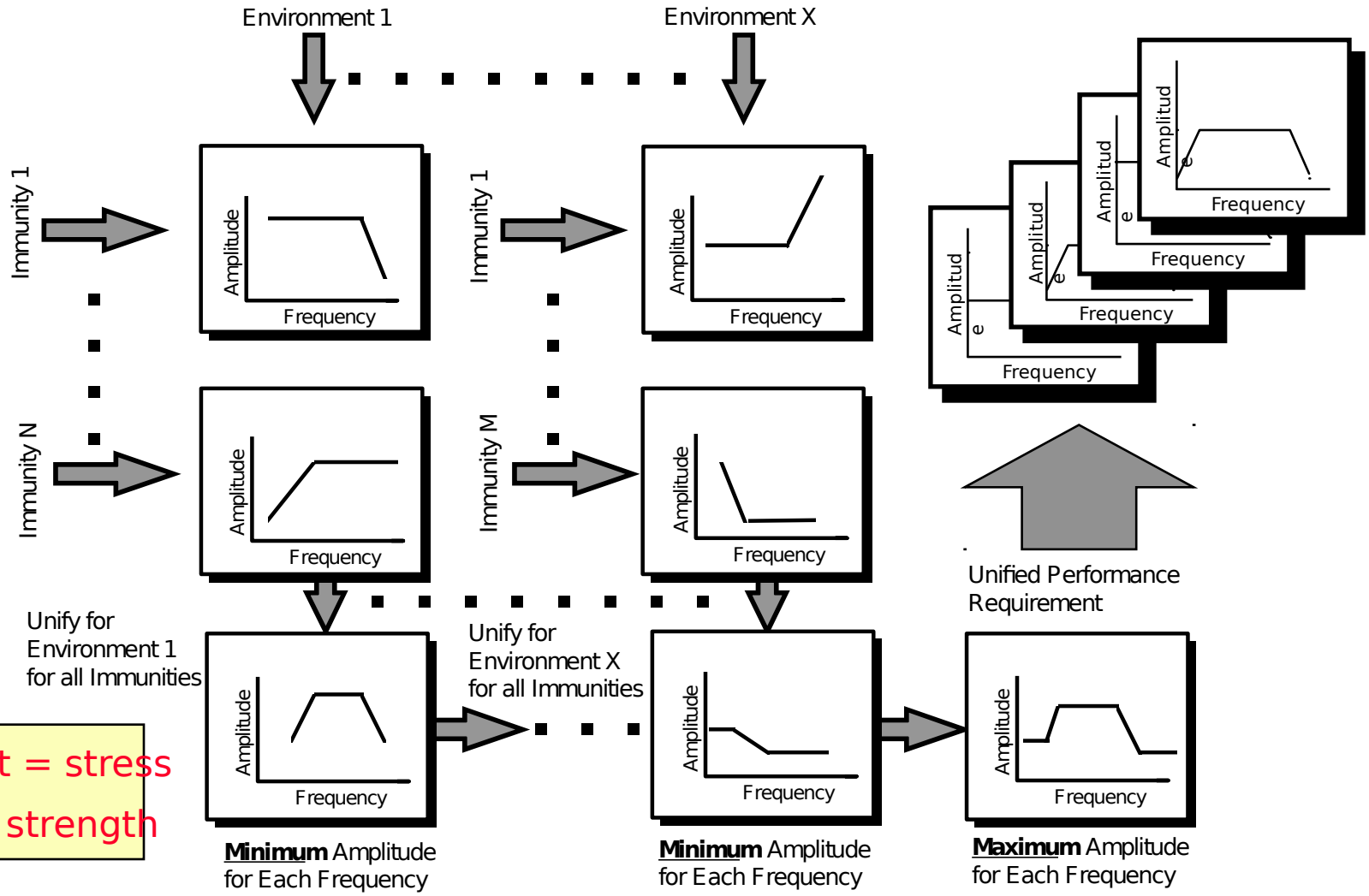
Performance Requirements Approach



Procedure tailored for

- Enclosure Ports
- Penetration Ports

Unification Approach



Environment = stress

Immunity = strength

Unified E3 Matrix Example

User Inputs

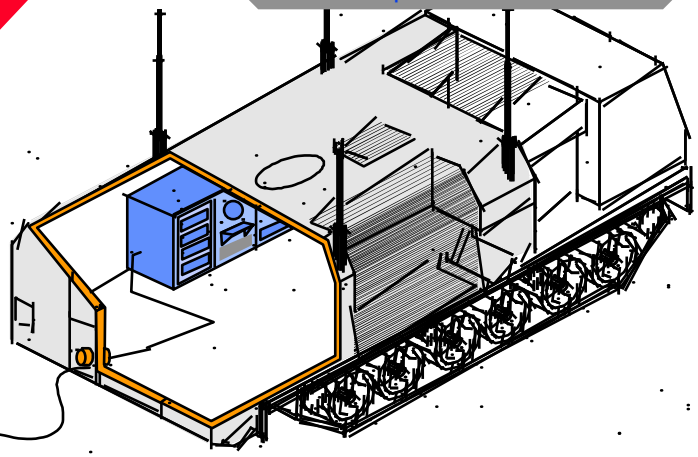
- System Description
  - Bradley C2V
  - Class 4, Light Armor
  - 7 Antennas
  - 1 Telephone Line
- Mission Needs
  - No Damage
  - Upset Allowed
- User Decisions
  - HEMP, Nearby Lightning
  - 6 dB Margin

E3 Information

- Environments
  - HEMP & Lightning Spectra
- Standards
  - IEC 1312
  - IEC 61000-2-9
  - IEC 61000-4-4
  - IIEC 61000-4-5
- Topologies
  - Example Layouts for Light Armor
- Definitions
  - Margin - The margin is the difference between the residual internal stresses and the electronics immunities.

Analytical Models

- Environments
  - Radiated
    - Fields from Nearby Lightning
  - Conducted
    - Infinite Line Model
- Immunities
  - Thevenin Load Response into 50 Ohms
- Topology Drawing
  - Single barrier
    - 1 enclosure
    - 8 penetrations
- Barrier Performance Requirements
  - Automated Computation of unified performance requirements



Bradley C2V System

- Class 4, Light Armor
- 6 dB Margin
- HEMP, Nearby Lightning
- IEC 1312
- IEC 61000-2-9
- IEC 61000-4-4
- IEC 61000-4-5
- Enclosure Port Performance Requirements
- 7 Antenna Port Performance Requirements
- Telephone Port Performance Requirements

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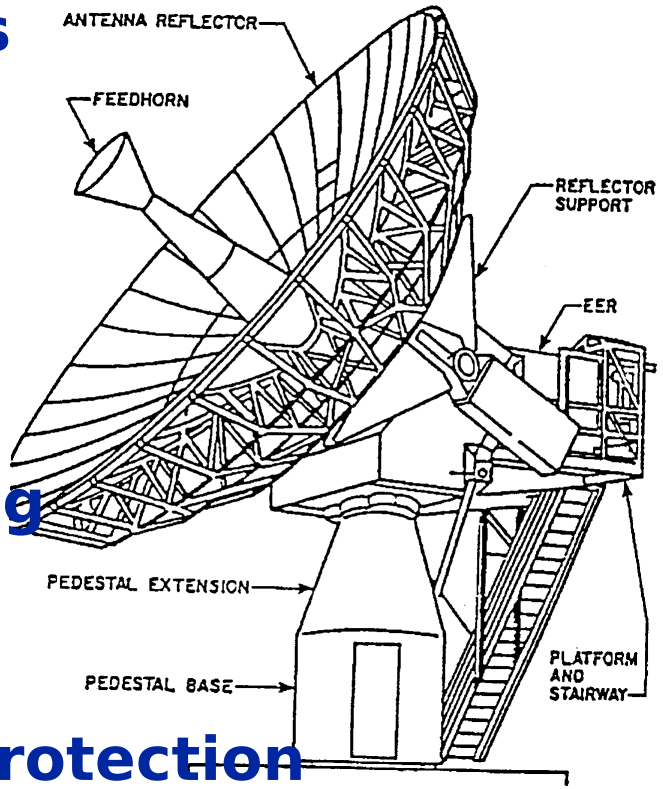
Evaluation of Existing System

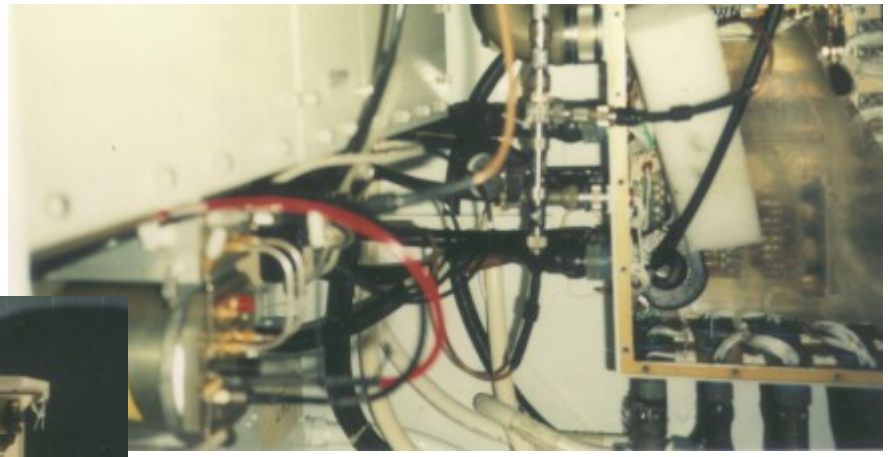
- **Satellite Communications Terminal**
- **Existing HEMP Test Data**
  - CW Illumination
  - Immunity Testing Using Pulse Current Injection
- **Evaluate Nearby Lightning Environmental Effects**
- **Signal & Control Port Evaluated (Penetration Protection Requirement)**

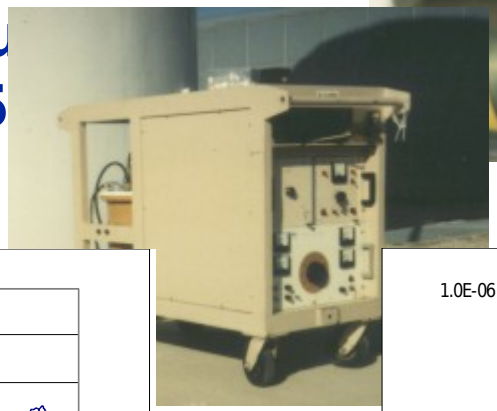


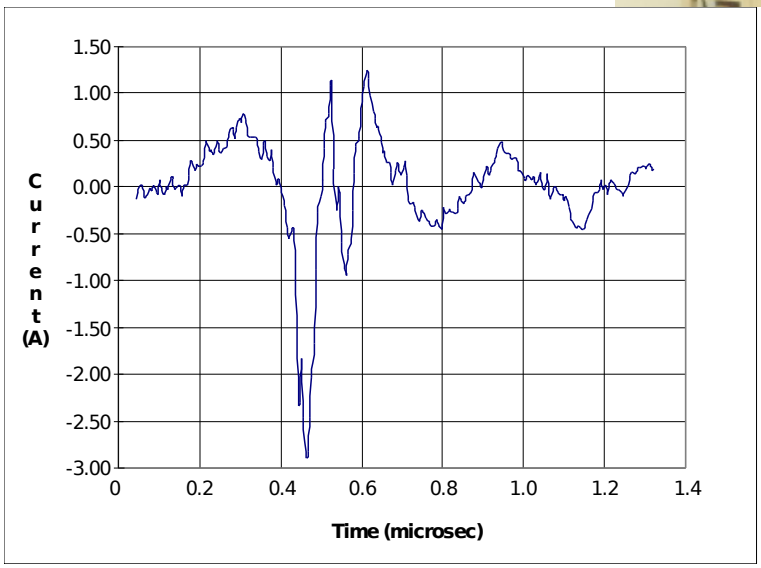
Custom Conducted Immunity

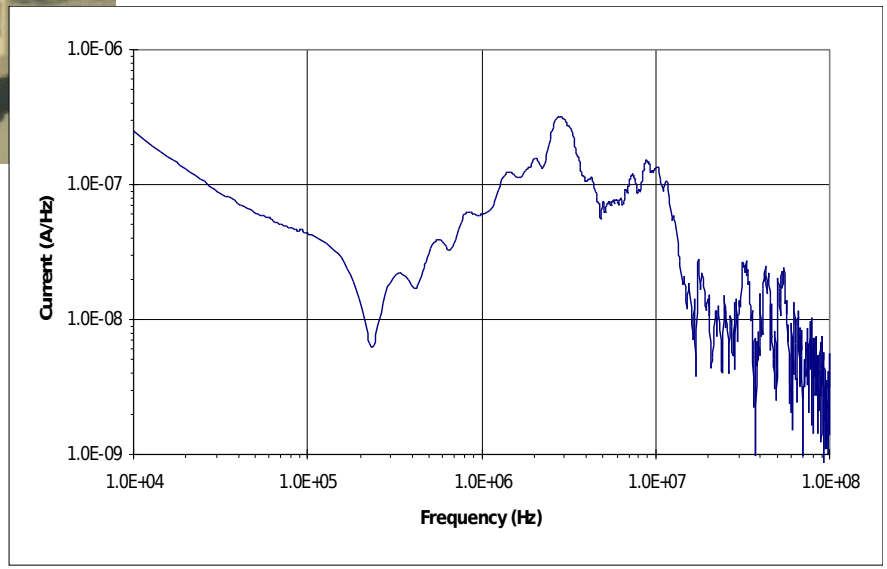
- **Immunity Testing (Strength) Performed at Worst Case HEMP Stress Level per Special Protective Measu MIL-STD 188-125**

$$I_s = 10\left|\frac{I_{cw}}{E_{cw}}\right| E_{EMP}$$



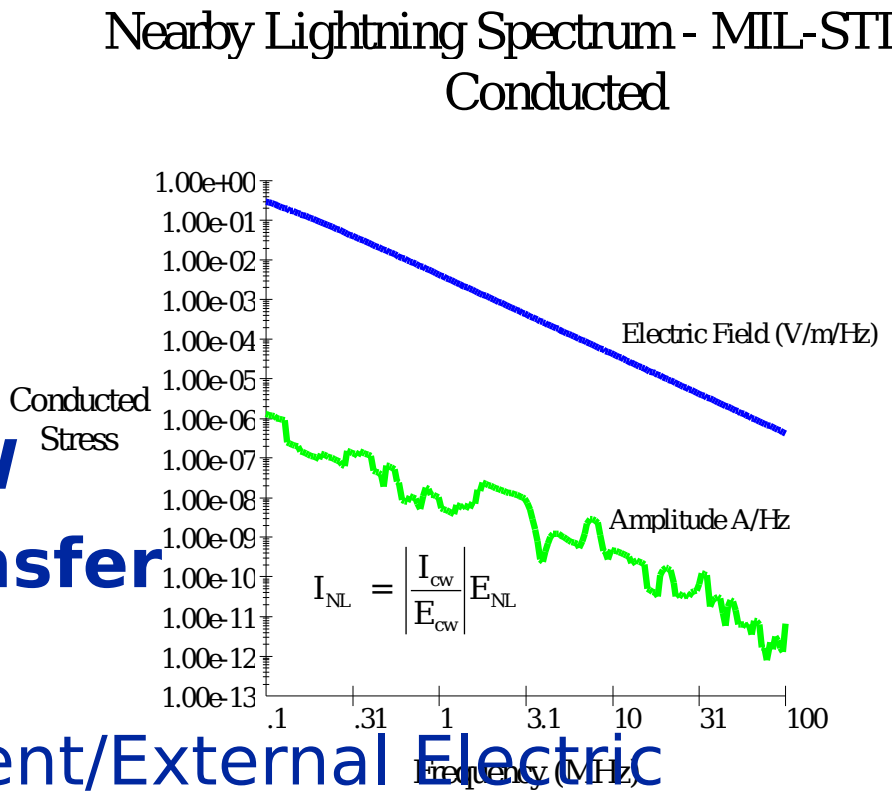






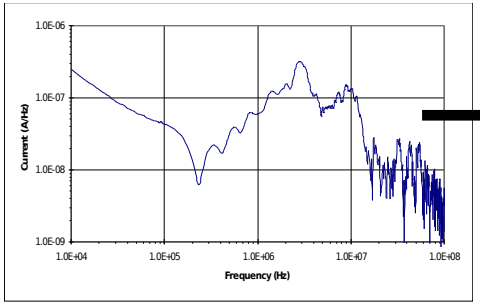
Nearby Lightning Conducted Stress

- **MIL-STD-464 Environment**
  - radiated field
  - at 50 m
- **Experimental CW Illumination Transfer Function**
  - Inner Coax Current/External Electric Field



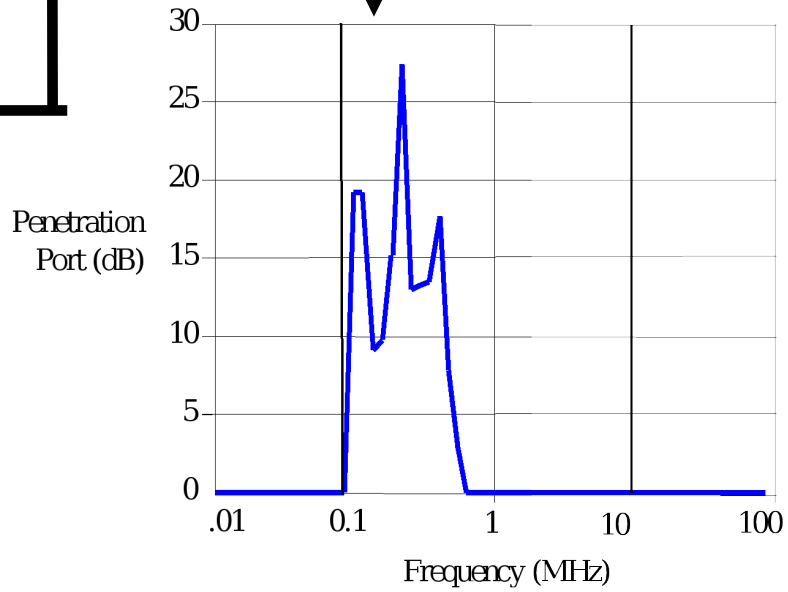
Penetration Port Protection Requirement For Nearby Lightning

Custom Immunity

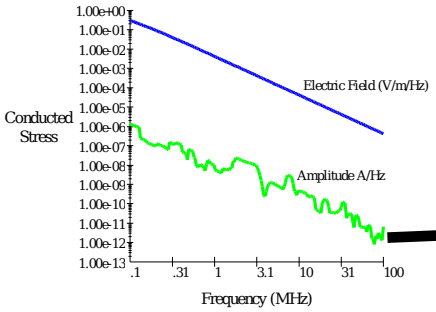


Residual Requirement

Margin of 6 dB



Nearby Lightning Spectrum - MIL-STD-464 Conducted



External Conducted Stress

Note: Some Ports Required No Additional Protection

Conclusions

- **High level immunity standards are usually related to an environment**
- **Commercial and military standards may be very similar**
- **Variations in test methods and specified quantities may make comparisons difficult**
- **Some commercial standards equal or exceed military levels**
- **DTRA's Unified EM Design software package**
  - Enables direct comparisons of environments and immunities
  - Generates combined system-level protection requirements (specifications) for multiple radiated and/or conducted (coupled) environments

Point of Contact

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